VINTAGE WORKBENCH

The Tektronix Type 130 LC Meter – Part 2
Restoration

By Alan Hampel, B. Eng. (Electronics, Honours)

Last month, Alan Hampel described how the valve-based T-130 LC meter worked. He also described how he purchased a non-working unit from eBay (with "non-working" omitted from the description). Now he opens it up and starts work on restoring it to its former glory.

I unwrapped the package from the eBay seller and took the T-130 cabinet sides off. It was covered inside and out with cigarette smoke gunk. That's not uncommon in old laboratory instruments. Instead of the cabinet being an attractive blue, it was a dull blue-grey.

The cause of the clunking noises was immediately apparent – there was no 6X4 in the rectifier socket, but a 1N2630 solid-state valve replacement rectifier was loose amongst the works.

The 1N2630 was no doubt put in the 6X4 socket by a previous owner. But it's about four times as heavy as the original valve, being solid epoxy and not mostly vacuum. It also has a larger diameter, fouling the socket retaining screws and preventing the socket fully gripping the pins; so it fell out.

A 1N2630 (left) was used instead of the original 6X4 (right) as the rectifier. Due to its larger diameter and weight, it came loose from the socket in transit, damaging one of the 6U8s.

The loose 1N2630 smashed one of the 6U8s and bent the plates of a trimmer capacitor. Annoying, but easily fixed. I also noticed the meter clear plastic casing was broken in one corner – the only corner not shown in the eBay photos.

Preliminary evaluation

I carefully straightened out the bent trimmer capacitor plates and performed a thorough search for glass fragments within the instrument and in the packaging. I only found two tiny pieces jammed in out-of-the-way spots, but not anywhere near enough to account for the smashed 6U8. So someone cleaned out almost all the glass before shipping, without replacing the smashed valve. Interesting.

The front panel glass was cracked along one edge. There was also grime and dirt inside and outside the case.

I then removed all valves, carefully noting which valves came from which sockets. It's a good idea to keep valves separate, even if they are the same type, especially if they are double-valves like 6U8 triode-pentodes and 6BQ7 twin triodes.

Such valves, when faulty, have a high probability of producing entirely different symptoms or no symptoms at all depending on which socket they are plugged into. Nor do you want to allow circuit faults to cause any more damage than has already occurred.

The T-130 came from the USA, so the next thing I did was to rewire the power transformer twin primaries for "234VAC" operation, and I also changed the fuse to one half the original amperage.

The seller supplied a power cord, with the correct US NEMA 3-pin female on the instrument end, and a standard US 3-pin male plug on the other end. That's no good in Australia, and it was a very short cord too, so I bought a longer NEMA power cord on eBay and changed the male end to an Australian 3-pin plug.

I then plugged the instrument into a Variac and slowly wound it up from 0V. Nothing dramatic happened (no smoke released), but when I got it up to 200V AC, I noticed that the front panel pilot light was still not lit. The lamp socket pins were bent and shorting out the heater wiring. More damage from the loose 1N2630, most likely.

I lengthened the short circuit and tried again with the full 230V AC mains. The secondary voltages on the power transformer were correct, so I

If you have a Tektronix instrument with this AC mains connector on the back, check the Earth pin. It may show high resistance due to a loose retaining nut.

plugged in a 6X4 taken from an old radio, and the 0B2 regulator. I knew the 6X4 was pretty weak, but the HT drain in the T-130 should be a lot less than a typical radio, and I needed to quickly work out what was what before contacting the seller.

I now had 260V and 149.5V on the HT rails, and 75V DC on the heater wiring, so things were looking good.

As the 6U8 in the V30 socket had been smashed, I plugged in a 6U8 taken from an ancient TV, checking that the heater wiring was still at +75V in case there was heater-cathode leakage. It was still good, and my CRO showed oscillation at about 140kHz.

Next, I plugged in V4, another 6U8, functioning as the variable oscillator. I was rewarded with weak oscillation on the CRO at about 140kHz, varying with the position of the front panel COARSE ZERO control. The heaters still measured +75V DC, so no major faults were apparent.

I proceeded to replace the remaining valves one at a time, checking the +75V rail each time, and was rewarded with front panel meter deflection, varying with the COARSE ZERO control. Now I knew there was nothing major wrong, so I probably wouldn't need any parts made from unobtainium to fix the set (eg, transformers or coils). I therefore decided to proceed with a full clean and restoration.

To conduct further tests, I connected a 415pF tuning capacitor to the UNKNOWN socket, set the capacitor to minimum, and adjusted the COARSE ZERO and FINE ZERO controls for a zero reading on the 0-300pF range. Slowly turning the tuning capacitor towards maximum, I noticed two things:

1) The meter reading increased from zero up about 80pF indicated, then slowly decreased back to zero at about 120pF from the test capacitor! I thought this might be a problem with the Schmitt trigger circuit, perhaps the 6U8 (V70).

2) As the tuning capacitor was turned, there were violent swings of the meter (and I do mean violent!) at certain settings. The CRO showed this was due to the Schmitt trigger breaking into RF oscillation.

Schmitt trigger circuits can sometimes oscillate if the valve is weak, or a resistor has gone high, usually because the positive feedback is insufficient to produce a definite snap action, but enough to oscillate with reactances present in the circuit.

14 rules of restoration

I follow 14 rules when repairing or restoring vintage professional electronics. I learnt these rules when I was employed servicing professional electronics at the tail end of the valve era. The rules maximise reliability and preserve resale value.

1) Never unsolder any component until, by deduction or in-circuit testing, you have proved that it is faulty.

2) Never put back any part that you unsoldered. Replace it with a new one (or NOS/NIB if a new part is unavailable).

3) Never replace non-electrolytic capacitors just because they are old and might be leaky. In professional equipment, leakage is a lot less likely as higher grade parts are used, voltages are lower, temperatures are lower than in typical valve radios, and circuits are more tolerant.

4) Never replace electrolytics just because they are old. The long-life types used in professional equipment are often perfectly good; there's no sense in sacrificing the factory look if there's nothing wrong with it.

5) Never swap valves of the same type around in the chassis as a diagnostic strategy or to fix a fault. Each valve stays where it is unless and until it is proved defective, at which point it is replaced with a new valve (these days, a NOS/NIB valve).

6) Clean and touch-up paint before addressing faults. Cleaning does sometimes cause more faults, and a nice clean instrument is a pleasure to work on.

7) After cleaning, check every single resistor for correct resistance (without unsoldering it) and every electrolytic in-circuit before proceeding with any diagnostic procedure. But don't replace anything found faulty yet.

8) Don't rely on an overall functional check or rely on a check against performance specifications. Go through each stage with a scope and verify that each stage works precisely as it should. Replace parts identified as out of specification as you go through each stage.

9) Some brands of capacitor are known to fail sooner or later. Replace these after each stage is verified good and the instrument meets and exceeds specifications. My T-130 did not have any such components.

10) Every single time you replace a component, do a comprehensive set of checks to verify both that the fault due to that component has been cleared, and that no new symptoms have appeared.

11) Where possible, replace resistors and capacitors with the same original type, or if you cannot obtain originals, use comparable components of the same vintage.

12) Clean and lubricate all switches, pots, variable capacitors and (later, during alignment/adjustment) presets. Don't just apply contact cleaner/lubricant to switch wafers and pots, do variable capacitors as well. Make sure you apply grease to wafer switch clicker mechanisms.

13) Never touch calibration adjustments or presets until there is nothing else left to do or check. Mostly, you'll find that an apparent need for adjustment (beyond minor touch-up) is in fact due to a faulty component.

14) Do not modify to fix a fault. Resist the temptation to modify to improve performance. Reputable manufacturers knew what they were doing.

Tektronix component strips and soldering

Tektronix installed pig-tail type resistors, capacitors, and other small parts on ceramic terminal strips (see photo below).

These strips have a glazed finish; they look nice and are rigid, which helps stable circuit operation and reduces vibration-induced failures. They also have negligible leakage and RF loss, and do not grow fungus in high humidity climates like phenolic tag strips can.

The strips also come in two different types, one that used nuts and bolts on the underside for mounting and the ones used here have snap-in fittings. The former was used in earlier models and could help determine the age of the meter.

Many people think these ceramic strips are unique to Tektronix, but a limited number of US manufacturers used them in tube-based military equipment. The Japanese test equipment manufacturer Meguro used similar ceramic strips.

Tektronix made these strips by coating the moulded but unfired strips with a paste of silver particles dispersed in an organic grease, then wiping the excess off. The wiping leaves the paste neatly confined within notches and slight depressions surrounding each notch.

Upon firing, the grease evaporated, leaving a microscopically thin coating of silver in and around each notch, bonded to the ceramic. They then tinned each notch ready for soldering in the components.

The downside of these strips is that silver readily dissolves in ordinary tin/lead solder, and solder does not stick to ceramic. Hence, using normal tin/lead solder will weaken the silver-ceramic bond and will, sooner or later, cause it to fail completely. In the factory, Tektronix used a tin/lead solder containing 3% silver, the 3% being sufficient to stop its affinity for more silver completely.

62% tin, 35% lead and 3% silver solder used to be available from Tektronix under part number 251-514, but they ceased selling it many years ago. Its melting point is 188°C.

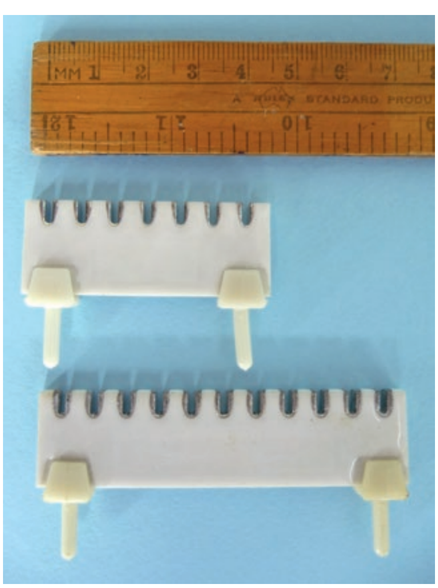
Note that this isn't "silver solder", which is a British term for brazing alloy. Nor is it modern lead-free electronic grade solder, which contains silver but has a significantly higher melting point that can damage the ceramic strips.

Tektronix usually installed a small roll of silver loaded solder inside their oscilloscopes. They often did not include it in cheaper instruments. If you have a Tektronix instrument that does not have the little roll, it's either because someone has swiped it, Tektronix never included it, or you have an instrument originally supplied to the military.

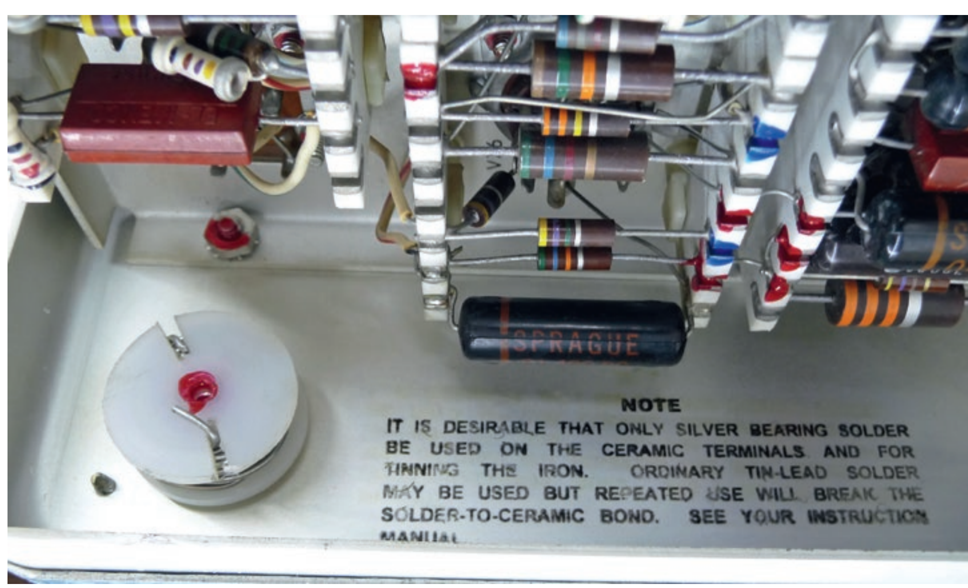
Fortunately, solder containing 62% tin, 36% lead, and 2% silver is readily available from RS Components (Cat 271-4172), along with element14 and other distributors.

When working on Tektronix ceramic strips, if you don't have the supplied roll, **always** use the modern 2% solder. Even 2% silver solder isn't optimal, and you probably don't know the history of the device, so you must assume the strips have already been weakened. New strips do occasionally show up on eBay, but only occasionally.

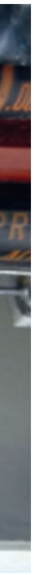
Never place the soldering iron tip within a notch and apply any force. The ceramic easily cracks if you do. Use a temperature-regulated chisel tip 5-6 mm wide and apply it to the side of the notch.



Two of the ceramic terminal strips, which many of the components mount on. The notches in this strip are lined with a silver alloy and the strip can be mounted via snap-in fittings (as shown) or bolt-on depending on type.



An example of the ceramic strips in place within the left-side of the chassis with components soldered in. You can also see a warning about only using "silver bearing" solder as tin-lead solder will eventually damage the silver alloy on the strips. The T-130 did not come with this solder, so I turned a replica reel (shown to the left of the note) and added 2% silver solder from RS Components. There is more detail on these strips and the recommended solder in the panel above.



I also noticed that the zero setting wandered about, and could not be brought to an actual zero beat, so that on the lowest range (3pF full scale), the meter had over full-scale deflection regardless of the COARSE ZERO control setting.

Contacting the seller

I sent a message to the seller via eBay, informing him that the instrument was not operational, thus not conforming to his description, and I explained why.

He promptly wrote back, apologising, and offering to send me two replacement NOS/NIB (new old stock/new in box) valves: a 6X4 and 6U8. I accepted that, but pointed out that the instrument uses five 6U8s and at least one more was probably faulty.

The seller then arranged for a US surplus valve dealer to courier one 6X4 and three 6U8s. They arrived two days later. They were mil-spec valves (W-suffix) too. I certainly couldn't complain about the after-sales service.

Making it pretty

Cleaning the cigarette smoke condensation off the cabinet was easy. I removed all cabinet parts from the central chassis and washed them, along with the front panel knobs. I did this in the sink with dishwashing detergent.

I used a soft sponge to clean the cabinet parts and a toothbrush for the knobs. I then thoroughly rinsed everything with running water and then Electrolube Saferinse, and dried the parts off. Everything came up like new, except for a few places where the paint had been worn off over the years.

"Tek Blue" touch-up paint used to be available from Tektronix under part number 252-0092-02, but not any more. Googling, I discovered that this paint was made by the Chemtron Aerosol division of Rudd Company Seattle. They no longer exist.

So instead, I bought the following from Bunnings: White Knight Rust Guard Quick Dry Advanced Enamel, Neutral Tint Base 500mL Stain Finish, colour coordinates W 36.5 B 16.5 D 27 E 16.

This gives an excellent match. 500mL is far more than I could ever use for touching up Tektronix instruments, but is the minimum they let me buy. I used a cotton bud to apply the paint where needed on the T-130 parts.

The UNKNOWN connector on the front panel is an old-fashioned UHF (SO-259) silver-plated socket, common on test gear made before the 1960s. It is much better than a BNC type in this application – a BNC connector does not have the mechanical strength to support accessories typically used with the T-130.

The connector was badly tarnished and missing many of its 'teeth', so I replaced it with a new one. Next, I reassembled the instrument using new screws, because the old ones were all corroded and unsightly. Shiny new screws make all the difference – the instrument now looked brand new – on the outside, anyway.

As with many electronics manufacturers in the 1950s and '60s, Tektronix painted internal cabinet and chassis screws and adjustments with what Tektronix staff called "Red Glyptal". Glyptal is a USA-based specialty paint manufacturer. The original formulation is no longer available, at least in small quantities.

Replicating Red Glyptal on the screws and adjustments is a nice touch in restoration. Many restorers use nail varnish, but it's far from ideal, in appearance or mechanical strength. A close equivalent is "BLR Tamper Proof Seal", available from RS Components (Cat 196-5245).

Estimating the age of a T-130

This can be difficult, as the T-130 was manufactured for 21 years, and there are no date codes on any of the parts, except the valves.

Of course, valve codes are useless, because you don't know what valves have been replaced during the instrument's life, and you don't know if any replaced valve was new, NOS, or merely an old valve somebody had on hand, good or otherwise.

You also can't rely on the serial number, at least not directly, as it is not known how many were sold in any given year, and that can vary widely. For an instrument like the T-130, which filled a niche need for the first time, there were probably brisk sales in early years, and then just a trickle each year, as new laboratories and factories started up.

For oscilloscopes, Tektronix used a few different coding schemes. These encoded the factory which produced the unit, country of origin, the revision level, and in some cases the date of manufacture. But it appears no coding scheme was used for the T-130, and the serial numbers were purely sequential.

In some cases, the serial number for smaller Tektronix instruments was sequential to the production line output, not to the instrument type.

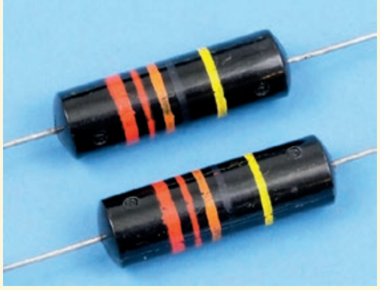
For example, a production line may have been making a batch of T-130s and then changed over to making T-123s (an oscilloscope preamplifier). If the last T-130 in the batch was given serial number 00226, the first T-123 would receive serial number 00227.

Thus, some smaller Tektronix instruments had large gaps in their serial number ranges. This likely applies to the T-130, as the number sold would not justify a dedicated production line.

Any Tektronix instrument with a serial number comprising a single letter and two digits is a pre-production sample or a laboratory prototype. Once in a while, these show up on eBay.

T-130 production started with serial number 101. The T-130 got a major facelift in 1958 (serial numbers 5000 and up) and a change in meter in 1965 (serial numbers 6168 and up).

If a T-130 has Sprague Black Beauty 160P capacitors (tubular capacitors with red printing), it was made 1960 or later. If it has Sprague Bumble Bee capacitors (colour-coded), it was probably made in 1960 or earlier.



Sprague "Bumble Bee" capacitors (left) mean the T-130 was likely made pre 1960, while "Black Beauty" 160P caps (right) indicate post 1960. The Bumble Bee caps usually leak, although leakage will often not affect the T-130's operation.

TYPE 130 L,C METER

Direct-Reading Inductance and Capacitance Meter

APPLICATIONS

Saves engineering time in circuit development work by providing quick inductance and capacitance readings even while circuit changes are being made. Aids in correct placement of critical components and leads.

Guard circuit produces a voltage of the same amplitude and phase as the voltage at the UNKNOWN terminals, but isolated from the frequency determining portions of the rest of the circuit. This permits separation of the capacitance to be measured from other capacitances and strays. Accurate measurements of direct inter-electrode capacitance in vacuum tubes can be made with ease.

The Type 130 can also be used for component testing, sorting, and color code checking on a production basis.

GENERAL DESCRIPTION

The unknown value to be measured will determine the frequency of the variable oscillator in the Type 130. This frequency is beat against a 140-kc fixed oscillator. The difference frequency is shaped and counted, causing meter deflection proportional to the difference frequency. The direct-reading meter is calibrated in microhenries and micromicrofarads.

Guard Voltage

Permits measuring an unknown capacitance while eliminating the effects of other capacitances from the measurements.

Five Ranges

Microhenries—0 to 3, 10, 30, 100, 300.
Micromicrofarads—0 to 3, 10, 30, 100, 300.

Accuracy

Within 3% of full scale.

Coarse and Fine Zero Adjust

Four-Inch Illuminated Meter

VACUUM TUBE COMPLEMENT

Fixed Oscillator	6U8
Buffer Amplifier	6U8
Variable Oscillator	6U8
Buffer Amplifier	6U8
Mixer	6BE6
Bistable Multivibrator	6U8
Guard Circuit Cathode Follower	6BH6
CF Clamp and Diode Clamp	6BQ7A
Rectifier	6X4
Voltage Regulator	OA2

OTHER CHARACTERISTICS

Size—5″ wide, 9″ high, 8½″ deep.

Weight—9 lbs.

Construction—aluminum alloy.

Finish—photo-etched anodized panel, baked gray wrinkle cabinet.

Power requirements—117/234 volts, 50-60 cycles, 40 watts.

Price **$195**

Includes: 1—P93C Probe
1—W130R Lead
1—W130B Lead
1—Instruction Manual

Recommended Additional Accessories

Type F30 Production Test Fixture. Speeds sorting and testing of capacitors and inductors $3.00

Type S30 Delta Standards, for calibration of Type 130 L,C Meters $22.00

Prices f.o.b. Portland (Beaverton), Oregon.

Here is a page from the 1954 Tektronix catalog; when they started to produce the T-130 LC Meter.
Source: **http://w140.com/tekwiki/wiki/Tektronix_Catalogs**

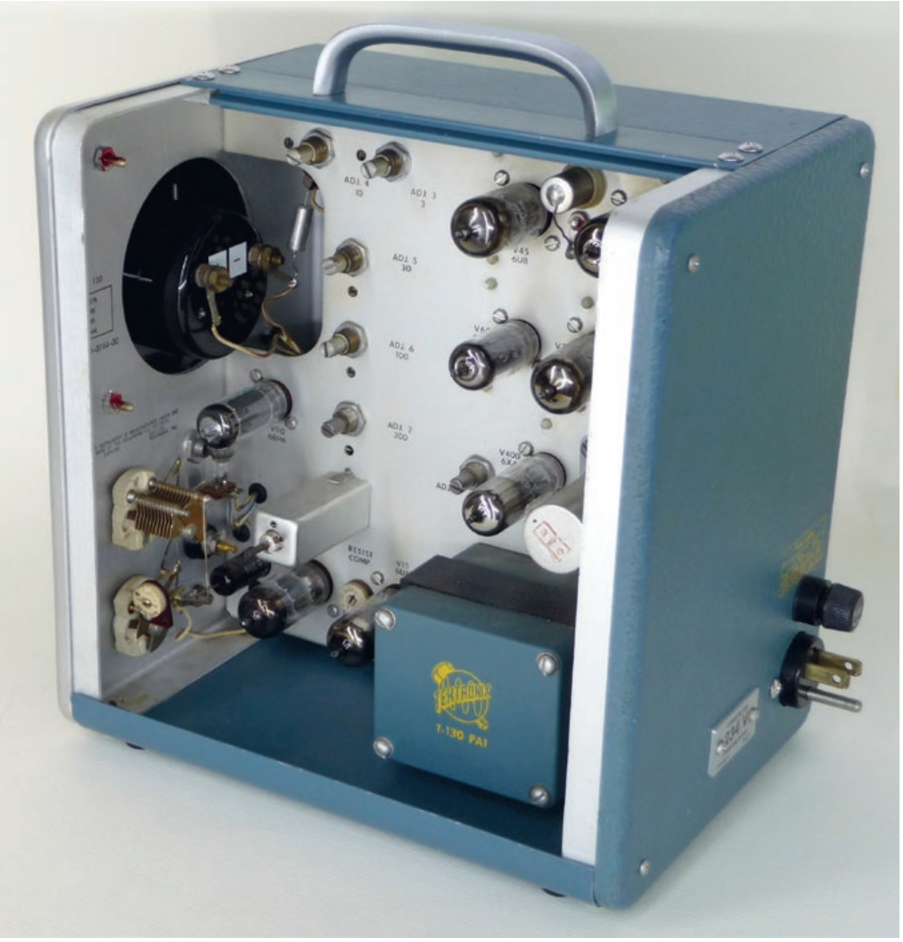
Safety hazards

I plugged in the power cord and checked the resistance from the Earth pin of the Australian plug to the T-130 chassis. High Earth lead resistance is a common fault in Tektronix instruments using a protruding NEMA 5-15 mains input connector. If you have one, best check it. Mine had an open-circuit Earth.

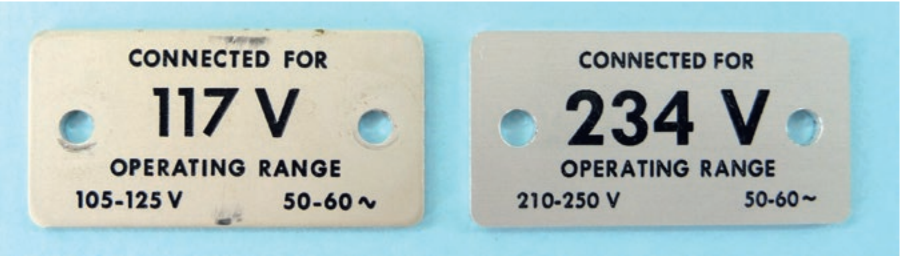
As is typical, the nut that secures the Earth pin to the connector backplate had worked loose. This is why you shouldn't use a mounting screw for an Earth connection, which isn't permitted by most authorities. There was tarnish on the Earth pin as well. I cleaned the pin and tightened the nut, using a drop of thread locker. I checked again with an ohmmeter – no perceptible resistance – good.

There is another safety hazard in the T-130. The range switch is a custom-assembled "Oak"-style three-wafer switch. The rear-most wafer selects the range setting capacitors and acts as the power switch on the primary side of the power transformer. So 230V AC is within a millimetre of the range selection common.

That's not very nice, Mr Moulton. It's an electric shock risk. One slip of a probe and the switch is history. And you can't buy a replacement now. I made a mental note never to probe with a voltmeter or CRO around the wafer while the T-130 is plugged in.



On the rear of the T-130 is the fuse, AC input and badge showing the voltage. A desktop NC milling machine was used to make a 234V AC badge to replace the 117V AC version shown below.



Internal cleaning

An internal clean was needed to get rid of accumulated cigarette smoke residue and the general dirt that accumulates in all valve equipment cooled by simple ventilation holes in the cabinet.

First, I washed the chassis, components and terminal strips with Safewash citrus solvent, applying it with a toothbrush and cotton buds.

Then, I went over it all again with Saferinse to get rid of the Safewash, and then again with isopropyl alcohol to remove the Saferinse. I was very careful to avoid getting any Safewash or Saferinse in the oscillator coils.

It is essential with old Tek equipment to thoroughly clean the terminal strips back to an uncontaminated glazed ceramic surface.

If you don't, the cigarette smoke residue and general grime will in time cause electrical leakage, if it hasn't already.

After cleaning, I took some photographs. Reviewing the photos, I realised the terminal strips still were not completely clean. So I repeated the whole process over again.

The T-130 was designed before high-grade polyester capacitors became available, but almost all T-130s, including mine, were made with professional-grade Sprague "Black Beauty" 160P capacitors (black tubular capacitors with red printing).

These seldom show any leakage. T-130s made before 160P production started in 1960 have Sprague "Bumble Bee" (colour-coded) capacitors, which usually do leak.

But quite a high leakage in the range capacitors (C90-C94), say 5μA, will only result in a slight change in FSD, which can be adjusted out in calibration. 5μA leakage in a radio grid coupling capacitor would have a disastrous effect on audio quality.

The only other tubular capacitor in the T-130 bypasses the 150V rail – leakage short of a definite fault there will have no effect.

Next month

Now that the T-130 was clean and safe, I could get into the nitty-gritty of figuring out what was wrong, fixing it, and then adjusting it back to its original factory-spec condition. But that will be in next month's article.

A brief history of direct-reading frequency meters

Digital frequency meters (counters) were not widely used until integrated circuits reduced the cost in the 1970s.

Imagine even a three-digit frequency counter implemented with valves. You'd need four twin valves for each decade counter, four for each display latch, five for each display decoder and eight more for time-base division. Plus another three for the power supply. That's a total of 50 valves!

But there has always been a need in design laboratories to measure frequency, and an analog meter of 1-5% accuracy was often good enough. So there have been analog frequency meters for just about as long as there has been electronics.

The earliest direct-reading frequency meters were just an amplifier with enough gain so that it is well over-driven, and the output is almost a square wave. The output is fed to a rectifier and moving-coil meter circuit via a small capacitor, so that the meter just gets a series of narrow pulses, one pulse per input cycle.

Due to mechanical inertia, the meter responds to the average current, so its deflection is proportional to frequency. This arrangement is shown in the upper circuit.

But this circuit has some serious disadvantages: if the input level is not sufficient to overdrive the amplifier, you get a low reading. In fact, the reading always depends on the input signal strength to some extent. The calibration also depends on not just the HT voltage and R1 and C1, but also on the emission of V2, even when V2 is completely overdriven.

Plus the contact potential of V3 causes a continuous deflection even with no signal. The pulse-width set by C1 must be a small fraction of the cycle time; otherwise, C1 will not discharge adequately, and the meter deflection will become excessive.

Howard Vollum, when a student at Reed College in 1936, wrote a thesis, "A stable beat frequency oscillator equipped with a direct reading frequency meter." The oscillator part was nothing remarkable, but his frequency meter significantly advanced the art. This is shown in the second circuit below.

Now V1 does not have to be overdriven. It can be an ordinary low-μ triode as its role is to provide a low-impedance drive to the transformer; this lowers its cut-off frequency.

The transformer provides push-pull drive to V2 and V3. V2 and V3 are small thyratrons and the circuit functions as a bistable (flip-flop).

Thyratrons (gas-filled triodes) function something like an SCR in series with a zener diode. If the grid is held sufficiently negative (-10V), no current flows in the anode and the grid. If the grid is taken less negative, anode current flow starts and ionises the gas. The anode current immediately rises to the maximum possible in the circuit.

The anode-cathode voltage stays close to 16V, regardless of what the anode current is. The grid is now more-or-less shorted to the cathode due to its position in the electron stream and proximity to the cathode.

Assume V3 is conducting (on) and V2 is off. The cathode of V3 is at 74V and C1 is charged to 74V, positive on the right. As soon as the left-hand end of the transformer goes sufficiently positive, V2 will snap on. V2's cathode rises immediately to +74V, so the right-hand end of C1 must rise to +148V, cutting off V3.

When the right-hand end of the transformer goes sufficiently positive, V3 turns back on, forcing V2 off again. The circuit flips back and forth at the input frequency, as long as sufficient input level is present.

C2 and C3 communicate short pulses to V4, which supplies two pulses to the meter for each input cycle.

So the output pulse amplitude and width is entirely independent of the input level. If the level is insufficient to trigger either thyratron, the action simply stops. As there are two pulses per input cycle, the meter pointer is a lot less likely to shudder with low (≲20Hz) input frequencies.

However, transformers were expensive, and Thyratrons cost more than hard vacuum triodes, yet were a lot less reliable and shorter-lived.

The next major advance came in 1941. National Cash Register Co. filed a patent (inventor L. A. DeRosa) disclosing a precision direct-reading frequency meter employing a flip-flop circuit based on two pentodes, triggered by an overdriven pentode amp.

The flip-flop ran at half the input signal frequency, but two pentode monostable circuits were triggered from each flip-flop pentode. The meter then received one clean and square monostable pulse for each input cycle. It was a little more accurate, a lot more complex but not much more expensive than the Vollum circuit. It retained the correct-or-nothing reading operation.

In 1951, Howard Vollum was now Tektronix chief engineer, and new engineer Chris Moulton was designing the new 'bistable' configuration used in the T-130. With the amplitude clamp circuit added by Moulton, his circuit is a lot simpler than the DeRosa method and just as accurate.

Most, if not all, subsequent designs for audio direct-reading frequency meters are derivatives of the Moulton and/or DeRosa methods.

The Hewlett Packard 500B/C Frequency Meter/Tachometer used a Schmitt trigger followed by a monostable briefly turning on (once per cycle), with a constant current source feeding the moving coil meter. With a rectangular or on/off pulse instead of a capacitor decay, the need to keep the pulse width small compared to one cycle is removed. SC